

Mutability

Announcements

Objects

(Demo)

Objects

- Objects represent information
- They consist of data and behavior, bundled together to create abstractions
- Objects can represent things, but also properties, interactions, & processes
- A type of object is called a class; **classes** are **first-class values** in Python
- Object-oriented programming:
 - A metaphor for organizing large programs
 - Special syntax that can improve the composition of programs
- In Python, **every value is an object**
 - All **objects** have **attributes**
 - A lot of data manipulation happens through object **methods**
 - Functions do one thing; objects do many related things

Example: Strings

(Demo)

Representing Strings: the ASCII Standard

American Standard Code for Information Interchange

8 rows: 3 bits

0 0 0
0 0 1
0 1 0
0 1 1
1 0 0
1 0 1
1 1 0
1 1 1

"Bell" (\a)

ASCII Code Chart

"Line feed" (\n)

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
0	NUL	SOH	STX	ETX	EOT	ENQ	ACK	BEL	BS	HT	LF	VT	FF	CR	SO	SI
1	DLE	DC1	DC2	DC3	DC4	NAK	SYN	ETB	CAN	EM	SUB	ESC	FS	GS	RS	US
2		!	"	#	\$	%	&	'	()	*	+	,	-	.	/
3	0	1	2	3	4	5	6	7	8	9	:	;	<	=	>	?
4	@	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
5	P	Q	R	S	T	U	V	W	X	Y	Z	[\]	^	_
6	`	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o
7	p	q	r	s	t	u	v	w	x	y	z	{		}	~	DEL

16 columns: 4 bits

- Layout was chosen to support sorting by character code
- Rows indexed 2–5 are a useful 6-bit (64 element) subset
- Control characters were designed for transmission

(Demo)

Representing Strings: the Unicode Standard

- 137,994 characters in Unicode 12.1
- 150 scripts (organized)
- Enumeration of character properties, such as case
- Supports bidirectional display order
- A canonical name for every character

聾	聾	聾	聾	聾	聾	聾	聾
8071	8072	8073	8074	8075	8076	8077	8078
健	腓	腳	腓	腓	腓	腓	腸
8171	8172	8173	8174	8175	8176	8177	8178
艱	色	艷	艷	艷	艷	艷	艷
8271	8272	8273	8274	8275	8276	8277	8278
菟	菟	荳	菰	菰	菰	荷	菰
8371	8372	8373	8374	8375	8376	8377	8378
葱	菰	菰	菰	葵	菰	菰	菰

http://ian-albert.com/unicode_chart/unichart-chinese.jpg

LATIN CAPITAL LETTER A

DIE FACE-6

EIGHTH NOTE



(Demo)

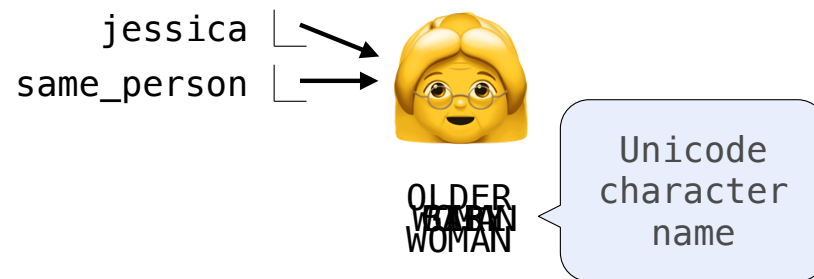
Mutation Operations

Some Objects Can Change

[Demo]

First example in the course of an object changing state

The same object can change in value **throughout** the course of computation



All names that refer to the same object are affected by a mutation

Only objects of *mutable* types can change: lists & dictionaries

{Demo}

Mutation Can Happen Within a Function Call

A function can change the value of any object in its scope

```
>>> four = [1, 2, 3, 4]
>>> len(four)
4
>>> mystery(four)
>>> len(four)
2
```

```
def mystery(s):      or      def mystery(s):
    s.pop()           s[2:] = []
    s.pop()
```

```
>>> four = [1, 2, 3, 4]
>>> len(four)
4
>>> another_mystery() # No arguments!
>>> len(four)
2
```

```
def another_mystery():
    four.pop()
    four.pop()
```

Tuples

(Demo)

Tuples are Immutable Sequences

Immutable values are protected from mutation

```
>>> turtle = (1, 2, 3)
>>> ooze()
>>> turtle
(1, 2, 3)
```

Next lecture: ooze can change turtle's binding

```
>>> turtle = [1, 2, 3]
>>> ooze()
>>> turtle
['Anything could be inside!']
```

The value of an expression can change because of changes in names or objects

Name change:

```
>>> x = 2
>>> x + x
4
>>> x = 3
>>> x + x
6
```

Object mutation:

```
>>> x = [1, 2]
>>> x + x
[1, 2, 1, 2]
>>> x.append(3)
>>> x + x
[1, 2, 3, 1, 2, 3]
```

An immutable sequence may still change if it contains a mutable value as an element

```
>>> s = ([1, 2], 3)
>>> s[0] = 4
ERROR
```

```
>>> s = ([1, 2], 3)
>>> s[0][0] = 4
>>> s
([4, 2], 3)
```

Mutation

Sameness and Change

- As long as we never modify objects, a compound object is just the totality of its pieces
- A rational number is just its numerator and denominator
- This view is no longer valid in the presence of change
- A compound data object **has an "identity"** in addition to the pieces of which it is composed
- A list is **still "the same" list** even if we change its contents
- Conversely, we could have two lists that happen to have the same contents, but **are different**

```
>>> a = [10]
>>> b = a
>>> a == b
True
>>> a.append(20)
>>> a
[10, 20]
>>> b
[10, 20]
>>> a == b
True
```

```
>>> a = [10]
>>> b = [10]
>>> a == b
True
>>> b.append(20)
>>> a
[10]
>>> b
[10, 20]
>>> a == b
False
```

Identity Operators

Identity

`<exp0> is <exp1>`

evaluates to `True` if both `<exp0>` and `<exp1>` evaluate to the `same object`

Equality

`<exp0> == <exp1>`

evaluates to `True` if both `<exp0>` and `<exp1>` evaluate to `equal values`

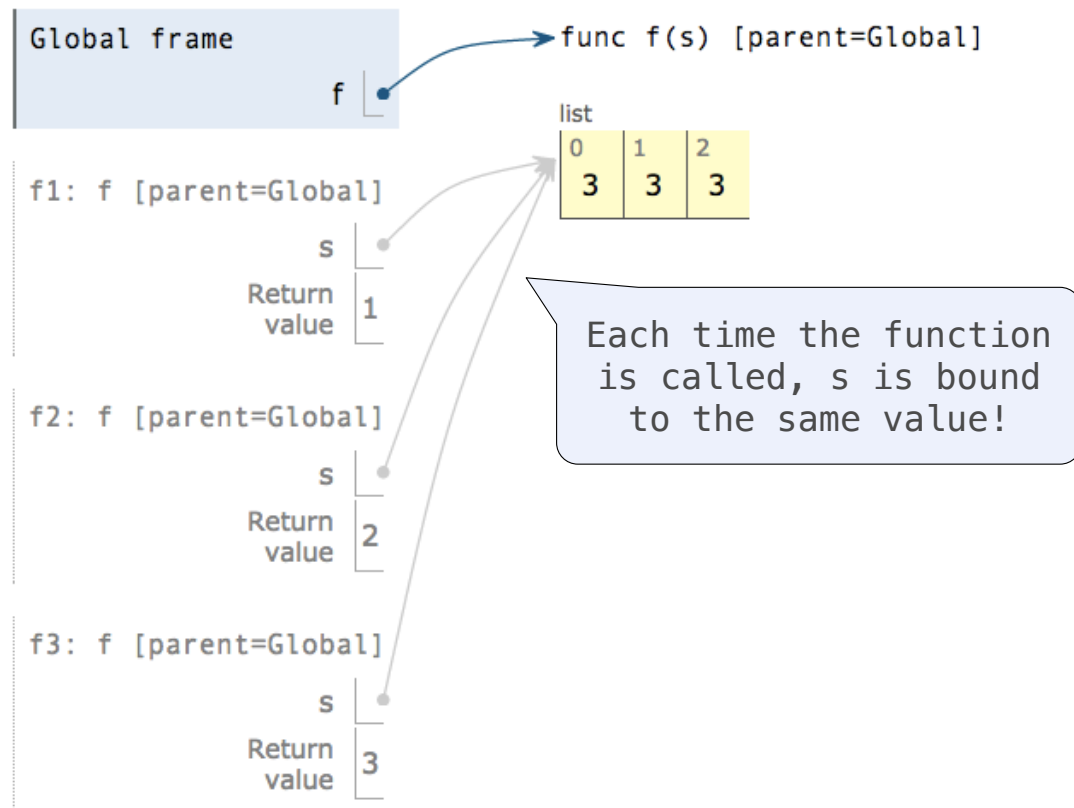
Identical objects are always equal values

(Demo)

Mutable Default Arguments are Dangerous

A default argument value is part of a function value, not generated by a call

```
>>> def f(s=[]):
...     s.append(3)
...     return len(s)
...
>>> f()
1
>>> f()
2
>>> f()
3
```



Mutable Functions

A Function with Behavior That Varies Over Time

Let's model a bank account that has a balance of \$100

```
>>> withdraw = make_withdraw_list(100)
```

In a (mutable) list
referenced in the parent
frame of the function

Return value:
remaining balance

```
>>> withdraw(25)  
75
```

Argument:
amount to withdraw

Different
return value!

```
>>> withdraw(25)  
50
```

Second withdrawal of
the same amount

```
>>> withdraw(60)  
'Insufficient funds'
```

```
>>> withdraw(15)  
35
```

Where's this balance
stored?

Mutable Values & Persistent Local State

